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(6) MECHANICAL APTITUDE VI,

A RE-ANALYSIS
OF THE ARMY AIR FORCE
BATTERY OF MECHANICAL TESTS

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A RE-ANALYSIS OF THE ARMY AIR FORCE BATTERY OF MECHANICAL TESTS

The purpose of this analysis is a re-examination of the Army Air Force factor analysis of mechanical tests ~~(1)~~ with respect to certain alternate views of rotation and simple structure. Since this battery represents the AAF's principal research in this area, it seems appropriate to examine the results and interpretations of the battery with respect to those of a similar study in the Navy Mechanical Aptitude Series. ~~(4,5)~~ The current paper constitutes a report in the latter series.*

It must be emphasized that it is not the intention of this paper to present a hypercritical review of the AAF study, but rather, to examine the similarities and differences in the two studies, and to profit thereby. In order to accomplish this, it is considered necessary to make the studies directly comparable. This is accomplished by rotating the configuration to an oblique rather than an orthogonal simple structure which is the form of solution which the AAF utilized. Since there seems to be something of an issue concerning these two types of solution, it appears appropriate to consider briefly the nature of simple structure and the implications of oblique and orthogonal structure.

Certain invariants exist in factor analysis, of which, one of the most prominent is the concept of configuration. A configuration is a system of vectors having a common origin and whose mutual relations are completely determined by their lengths and angular separations. Thus, the configuration is independent of any particular reference system, orthogonal or oblique. If, as an empirical fact, the vectors lie in certain hyperplanes, the configuration is said to possess simple structure. Any linearly independent set of (r - 1) vectors in an r-dimensional space is adequate to define a hyperplane. If we have n vectors in this system, then the number of linearly independent combinations of the n vectors taken (r - 1) at a time exhausts the total possible number of hyperplanes. This will, in general, be a large number. However, if simple structure exists in the configuration, most of these will be located in groups so as to define the same or approximately the same hyperplane, or rather, set of hyperplanes. No more than r hyperplanes can be defined in this manner, excluding the possible case of dependent composite factors, although it is possible that less than r hyperplanes may be adequately defined. The practical problem of rotation is simply the demonstration of (a) the existence and (b) the location of these more general hyperplanes.

If simple structure is present in any given configuration, these r, or possibly less than r, hyperplanes will be determined uniquely within the restriction of the degree of overdetermination, which may be required to accept the hyperplanes with any degree of confidence. It is in this sense that simple structure is unique. There is nothing inherent in this theory which would place the general restriction of orthogonality on the normals which define the hyperplanes and which form the reference system in which the simple structure is interpreted.

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The significant loadings on these normals represent that component of the variance of each variable which is independent (uncorrelated) of the variables which define the hyperplane. The essential differences between orthogonal and oblique rotation can perhaps be emphasized by the use of the simplest possible example. Consider the case of two vectors, j and k, with angular separation θ, where $0^{\circ} < \theta < 90^{\circ}$, and the correlation $r_{jk} = h_j h_k \cos \theta_{jk}$. The symbols, h_j and h_k, represent the lengths of the vectors. If an attempt is made to impose reference vectors, x_1 and x_2, on this configuration a number of problems immediately arise. If the reference vectors are to be kept orthogonal, then a priori decisions must be made concerning their placement. One possible decision would be to place one of the reference vectors collinear with one of the test vectors. The result would be to define one of the tests as "pure," whereupon the other necessarily becomes complex. If the other possibility of rotating the reference vectors such that each test vector has a loading on both reference vectors is followed, it is apparent that again some a priori criteria must be utilized. However, if the restriction of orthogonality is removed, it becomes possible to rotate the reference system to a position which requires no a priori assumptions. Each reference vector is placed orthogonal to one of the two test vectors, j and k. Thus the reference vector orthogonal to k represents a fictitious variable which is uncorrelated with k. Thus the projection of j on this reference vector represents that component of its variance which is uncorrelated with k. In the interpretation of a factor, it is necessary to consider loadings which represent only the independent components of variance, independence being defined in terms of the other tests in the battery and not by an arbitrary orthogonal system. A procedure such as this frequently results in correlations between the factors which may themselves be of fundamental importance. The application of the multiple factor methods to these second order correlations has been discussed in detail by Thurstone (2).

Description of the Variables

A complete description of each of the variables in this battery is presented in Army Air Force Aviation Psychology Research Reports, Report No. 5, Printed Classification Tests (1). However, for the convenience of the reader, summary descriptions of the tests will be given.

1. Mechanical Principles - This test is similar to Bennett and Fry's Mechanical Aptitudes Test. A series of mechanical problems or situations are presented pictorially. The solution of these problems requires the application of elementary mechanical principles.

2. Mechanical Movements - This is an adaptation of Thurstone's Mechanical Movements Test. A series of mechanical movements are presented schematically, concerning which questions are asked relating to the direction and temporal organization of movement, consequences of specific movements of certain parts, etc.

3. Mechanical Information - This is a verbal information test concerning the structure, function, and repair of common mechanical devices. Most of the items relate to a knowledge of automotive mechanics.

4. Tool Function - In each of the items of this test either one tool is shown pictorially and the subject makes the choice of its proper function from five verbally presented functions, or, a tool function is described verbally and the subject selects the proper tool to fulfill this function from five pictorially presented tools.

5. Mechanical Functions - A pictorial test in which the items consist of single or paired presentations of mechanical devices. In the single presentations, questions are asked concerning the function of specific elements of the device. The majority of the items are paired presentations of two different devices which have similar functions. The subjects indicate the corresponding parts of each which have analogous functions.

6. Pattern Comprehension - This is an adaptation of Thurstone's Surface Development test. The subject is required to match the edges and indicated folds of a flat pattern with the appropriate edges of an isometric drawing showing the three-dimensional object which is formed by the proper folding of the flat pattern.

7. Pattern Assembly - This is essentially a paper-pencil form-board test. Several forms or parts are shown which when fitted together form a simple geometric figure such as a square or circle. For each set of these, five completed figures showing the outline of the parts are given. The subject indicates which of the five is made from the given pieces.

8. Physics - This is a verbally presented, 30-item, multiple-choice test concerning knowledge of the principles of physics at approximately a high-school level.

9. Reading Comprehension - This is a standard reading-comprehension test in which three passages of approximately 250 words each on technical subjects are given. There are seven multiple-choice questions following each passage.

10. Mechanical Comprehension - A sub-section of the AAF Aviation Cadet Qualifying Examination, Form B, in which complex mechanical devices are presented pictorially, by a cross-section view, in conjunction with a brief passage describing the apparatus and its function. Multiple-choice items follow each of these which are quite similar to those of the mechanical movements tests.

11. Mechanical Comprehension - A test similar in content and form to variable 10, which was taken from Form D of the Aviation Cadet Qualifying Examination.

12. Arithmetic Reasoning - A 30-item test which consists of verbally presented arithmetic problems of the type commonly encountered in 7th and 8th grade arithmetic or elementary algebra.

13. Spatial Orientation - An aerial photo is shown, below which are six circular sub-sections of the given photo. These sub-sections are to be matched with the corresponding lettered sections of the larger photograph.

14. S.A.M. Complex Coordination - This is a psychomotor test in which the subject is seated at the simulated controls of a plane. One light is simultaneously presented in each of three banks of lights, one vertical,

two horizontal. The subject is then required, by manipulation of the stick and rudder controls, to match the three stimulus lights with response lights situated in rows which parallel the stimulus banks. When this has been accomplished, the apparatus automatically presents three other stimulus lights which are to be matched. The subject proceeds in this serial manner for an eight-minute test period.

15. Nearest Point - In this test, three points are presented in a field of distractors which occasionally serve an illusory function. The subject is required to judge which of two lettered points is closer to the third point.

16. Shortest Path - Two points are connected by three non-intersecting, irregular lines. The subject selects that line which represents the shortest linear distance between the two points.

17. Shorter Line - This test is very similar to Nearest Point. A number of lines radiating from a common point are presented with the addition, in most items, of other distractors, e.g., lines, circles, irregular forms, etc. Two of the lines are lettered and the subject determines the shorter of these two lines.

The centroid factor matrix as presented by the AAF is given in Table 1. The rotated, oblique factor matrix which was obtained by the use of the methods of radial rotation and which form the basis of the interpretations is given in Table 2.

The transformation matrix, the matrix of cosines of the angles between the reference vectors, and the correlations between the primary factors are presented in Tables 3, 4, and 5, respectively.

Interpretation of the Factors

The interpretation of factors is a subjective process; while it is true that the interpretations must in some way be a function of the interpreter's theoretical set, his psychological experience, his inductive ability, etc., the requirements and constraints of the factorial methods permit only certain limited possibilities, and conversely, only limited degrees of precision. The principles of induction require that the characteristics of the factor in question must not only have produced variance in all of the variables which have loadings on the factor, but also, that the variance of none of the other variables in the battery can be attributed to these characteristics. Precision is limited in that several such characteristics may satisfy these criteria with little or no basis for choosing among them. Precision can be increased only by further experimentation.

It will be apparent that differences exist between the original and the current interpretations of some of the factors. To some extent this is a function of the oblique rotation, but, more properly, it reflects alternate interpretations. An attempt has been made to present the reasons for selecting each of these alternate interpretations. There has been little hesitation in utilizing the results of other factorial studies, particularly other AAF analyses, in the interpretation of certain of the factors. This is justified by the considerable overlap of variables in the various AAF analyses, and was done to insure an adequate account of those factors which seem important in the mechanical aptitude domain. Only cursory attention will be given to those factors which have been found repeatedly in other studies.

Factor A

Principal Loadings on Factor A

Variable	Test Name	Loading
4	Tool Function	.64
3	Mechanical Information	.41
5	Mechanical Functions	.36

This factor is interpreted as mechanical experience or information. The tests require knowledge of the nature and function of tools, of the meaning of technical terms, and of mechanical functions associated with these terms. It might appear that a factor of this type is of considerable importance in the mechanical aptitude complex, but its importance cannot be viewed as fundamental. It is easily seen that experience or information factors of many types, e.g., musical, artistic, photographic, etc., could be found in any battery in which several tests are included which rely on a knowledge of the substantive content of a particular delimited field. To produce this type of factor it is only necessary that the experimental population be differentially skilled in one of these areas. These factors are largely cultural artifacts. Their main value in the investigation of an aptitude is not in their existence, per se, but rather, in the cognitive and temperamental characteristics of the individuals who have high scores on such a factor.

It is possible that Factor A may be regarded in a restricted sense as a partial criterion measure of mechanical aptitude. As stated in (1),

> ". . . unusual amounts of information in mechanics may stem from . . . (1) the tendency or desire to seek mechanical experience, (2) superior ability to profit by mechanical experience, and (3) unusually rich opportunity to gain mechanical experience."

The likelihood that interest and aptitude are positively related is great, and certainly most adults with high mechanical aptitude have attained considerable knowledge of mechanical things. There are, of course, both complete and differential exceptions to this, and these exceptions enable us to isolate the various abilities in the aptitude, although they are expected to be positively correlated with the experience factor. In Table 5, it is seen that Factor A correlates with Factor E (.56), Factor F (.49), and Factor D (.22). These are, respectively, a space factor concerned with the visualization of movement, a factor involving spatial relations with respect to body orientation, and a strength of closure factor. This seems highly reasonable with respect to the preconceptions concerning the nature of the underlying abilities in the mechanical aptitude complex. A further discussion of this is deferred to the description of the second order analysis.

Factor B

Principal Loadings on Factor B

Variable	Test Name	Loading
13	Spatial Orientation	.54
16	Shorter Path	.46
2	Mechanical Movements	.36
6	Pattern Comprehension	.31
7	Pattern Assembly	.28
5	Mechanical Functions	.22

It is quite evident that this is the perceptual speed factor which has been found in many other studies. There is one point of difference between this factor and the perceptual speed factor of the original analysis which should be mentioned. An attempt was made to solve for the transformation matrix which would reproduce their orthogonal solution from the centroid matrix. From this, it was obvious that a computational error had been made. Variable 16, Shorter Path, which had a reported loading in the original analysis of .06, should have been .45. Thus, its appearance on Factor B is not surprising; indeed, it would have been more surprising had it not appeared.

Factor C

Principal Loadings on Factor C

Variable	Test Name	Loading
9	Reading Comprehension	.68
8	Physics	.55
12	Arithmetic Reasoning	.37
10	Mechanical Comprehension	.28
11	Mechanical Comprehension	.28
6	Pattern Comprehension	.22
5	Mechanical Functions	.20

This factor is characterized by the verbal nature of the test item presentation in all variables with the exception of Pattern Comprehension. The items of the pattern comprehension test constitute a type of problem which can be presumed to be affected by training in such courses as mechanical drawing, projective drawing, and sheet metal work. This fact, which illustrates the possible partial source of variance of this variable, and the obvious scholastic nature of the other tests would suggest that, in an educationally heterogeneous population, this factor may be interpreted as a function of educational experience. Because of this ambiguity and since this factor is not viewed as important in mechanical aptitude, it is merely given the general label Verbal-Scholastic.

Factor D

Principal Loadings on Factor D

Variable	Test Name	Loading
17	Shorter Line	.64
7	Pattern Assembly	.45
15	Nearest Point	.33
16	Shortest Path	.23

The interpretation of this factor deviates considerably from that offered by the AAF. They interpret it as,

> ". . . a length-estimation factor involving the comparison of lines or simple distances between points. It may involve more complex estimates than those of linear dimensions."

It is difficult to refute this interpretation conclusively, since obviously linear comparisons do occur in each of these tests. However, doubt is cast upon it, since the differences in the lengths compared are supraliminal in almost every item. It is doubtful that this is a major source of variance in these tests unless the factor be interpreted as a simple speed of linear discrimination. This argument is weak because of the relative independence of Factor D and Factor B, which is the perceptual speed factor.

A more fruitful observation may be that most of the items are presented in a distracting, and occasionally an illusory, perceptual field. The ability to hold or maintain the appropriate elements of a configuration in a distracting field has been described by Thurstone (5) and labeled the second closure factor, C_2. Factor D of this analysis is believed to have these characteristics and is similarly interpreted.

An alternate, and perhaps more general, view of the C_2 factor is that it represents the ability to maximize the strength of the appropriate elements of the field (figure) and simultaneously to minimize all other elements (ground). The C_2 factor is then viewed as a minimax function of the figure-ground relation.

Factor E

Principal Loadings on Factor E

Variable	Test Name	Loading
1	Mechanical Principles	.47
11	Mechanical Comprehension	.44
2	Mechanical Movements	.39
3	Mechanical Information	.32
10	Mechanical Comprehension	.26
8	Physics	.25
6	Pattern Comprehension	.17

The Space I factor, S_1, may be defined as the ability to maintain the objectively invariant structural relations of a rigid assymetric configuration as it undergoes simple translation of position in two- or three-dimensional space. However, if two or more such structures are permitted to move with respect to each other in only specified manners, the specification being determined by the part-whole relation, another factor is involved. A factor of this type has been described by Thurstone and designated Space II, S_2. The AAF factorial studies (1) have also frequently reported a similar factor which they label visualization and define as:

> " This visualization factor is strongest in tests that present a stimulus either pictorially or verbally, and in which some manipulation or transformation to another visual arrangement is involved."

It is believed that this interpretation does not sufficiently differentiate the S_2 or visualization factor from the S_1 factor. The important aspect seems to be the manipulation or rearrangement of the internal parts of a visual configuration within certain restrictions that preserve the integrity of the configuration.

This factor was first present in a battery in (3) although its nature has not been evident until recently. L. R. Tucker's unpublished re-rotation of that battery to an oblique structure, W. Zimmerman's re-rotation to an alternate orthogonal structure, and the research of the AAF have served to clarify its nature. In that battery it is interesting to note the presence of the Disarranged Words test on the S_2 factor. In this test the subject is given a series of words, the letters of each in random order. The task is to rearrange the letters within the restrictions that all the letters be used to form complete words. Another test, Disarranged Sentences, in which the order of the words is scrambled but the words themselves remain intact, does not appear on this factor. This suggests the task to be a perceptual rearrangement of parts, which have little inherent meaning, to form meaningful wholes, rather than a conceptual rearrangement of meaningful parts to meaningful wholes. This example is used as an illustration of the greater generality of this factor, in that it is not limited to the solution of mechanical problems as the present battery might imply. Its importance in the solution of such problems is obvious.

A critical point of difference between the AAF battery and the Navy group-test battery is the appearance of a mechanical experience factor independent of the S_2 factor. In the Navy group-test battery only one factor was found which was composed of essentially the same tests which appeared on two factors in the AAF battery. The tests involving principally mechanical experience or information, viz., mechanical experience, mechanical comprehension, and electrical experience, had high loadings on this factor. The tests, which, in the AAF battery, were principally present on the S_2 factor, viz., mechanical movements, surface development, had only moderate loadings on this factor.

The explanation of the "disappearance" of one of these factors probably lies in the homogeneity of the population, and consequently may be viewed as an effect of selection. The subjects of the Navy study were all either third or fourth year students in a technical high school, and, as such, had considerable communality of mechanical experience and training. The technical courses, e.g., machine shop, automobile repair, mechanical drawing, sheet metal work, etc., provided sets of rules, principles, and techniques for the solution of such mechanical problems. It is likely that a group of this type would automatically adopt a set such that the solution of these problems would involve only an application of the principles and techniques in which they have been trained, and consequently only a mechanical experience or information factor would appear. A more heterogeneous population, such as the AAF employed, would be required to reveal both the S_2 and the experience factors.

Factor F

Principal Loadings on Factor F

Variable	Test Name	Loading
14	S.A.M. Complex Coordinator	.43
2	Mechanical Movements	.31
10	Mechanical Comprehension	.25
13	Spatial Orientation	.22
1	Mechanical Principles	.22

The interpretation of this factor would be difficult on the basis of this battery alone. However, a factor involving these tests among a number of others has frequently been found in the AAF research (1). Since it would appear to have considerable importance in mechanical aptitude, the results of these other studies will be utilized in the interpretation of Factor F. It seems reasonably clear that this is the factor which has been labeled "Spatial Relations" and defined as:

> "This is the spatial relations factor which seems to involve relating different stimuli to different responses, either stimuli or responses being arranged in spatial order. It is not clear whether the apprecia-tion of spatial arrangement of stimuli or the reactions separately is the key to this factor."

Other tests which have consistently had high loadings on this factor are Instrument Comprehension I, Instrument Comprehension II, Table Reading, Discrimination Reaction Time, Planning a Course, Cubes, Aerial Orientation, and Visualization of Maneuvers. These tests are described in (1).

The common aspect of this group of tests seems to be the facility in the control or determination of the direction of movement with respect to the body orientation, i.e., right-left, up-down, and forward-backward. The tests which have been found on this factor have been of both the paper-pencil and the psychomotor varieties; in addition, they have been presented in oral, written, and spatial-pictorial form. These facts have led to discussions of the relative importance of the perceptual and the motor components. However, if attention is directed to a possible central decision function, a solution may be provided. A factor of this sort would seem to be of fundamental biological importance.

Since the term "spatial relations" has been used in so many and varied contexts, it appears particularly ambiguous as a label for this factor. Accordingly it seems appropriate, both because of this ambiguity and in order to direct attention to the control aspect, to use N. Wiener's term, Cybernetics. To recapitulate, the critical element of the cybernetic factor seems to be the facility of discriminatory decision in which the decision relates to the potential direction of movement.

Factor G

Principal Loadings on Factor G

Variable	Test Name	Loading
15	Nearest Point	.49
12	Arithmetic Reasoning	.45
6	Pattern Comprehension	.32
16	Shorter Path	.22

Although this factor is not clearly defined by many tests, it is reasonably evident that it is a general reasoning factor. This agrees with the AAF interpretation. Their discussion of this factor attempts to justify the presence of variable 15, Nearest Point, on the basis of a sampling artifact, since in this battery the correlation between it and arithmetic reasoning was .36, and in another battery, only .10. It is possible that something peculiar has occurred in this case, but it would appear rather easy to rationalize. Nearest Point, as well as a very similar test, Shorter Line, had loadings on Factor D which was interpreted as the figure-ground minimax function. It is certainly considerably more difficult to maximize the figure and minimize the ground in the case of Nearest Point where the figure consists of merely three disparate points than in Shorter Line in which these points are connected. It could be that the difficulty of resolving these problems using a function as described for Factor D resulted in many of the subjects utilizing a general reasoning process to minimize the illusory effect of the distractors. This particular battery gives us few clues as to the nature of this general reasoning process, but it seems plausible to consider Factor G as such.

Second Order Analysis

The correlations of the primary factors, Table 5, were factored, using the centroid method of factoring, and rotated to an oblique simple structure. This factor analysis is presented in Tables 5 to 10 inclusive. Interpretation of these or any other second or higher order factors should be approached with caution. It may be that such factors represent trivial components of selection, motivation, test form, etc.; there is also the possibility that they are parameters of fundamental importance. No single analysis can provide an answer to these questions, but only the consistent identification of the same factors in many batteries with many types of populations will permit this assessment. With reference to the matter of selection effects producing these factors, it should be remembered that there are at least two ways in which selection can operate. If the activity of the experimenter in choosing his subjects is all that is represented, the factors would probably be regarded as trivial. However, it is possible that natural selection of some type is operative, and the discovery of such facts would undoubtedly be of paramount importance.

The second order factors of this study are given in Table 7. Factor K, which is composed of first order factors B and C, the Verbal-Scholastic and the Perceptual Speed factors probably represents some complex in the area of reading ability. Factor L, composed of General Reasoning, the Figure-Ground Minimax Factor, and, to some extent, the Cybernetic factor, demonstrates some common element in the reasoning domain, perhaps noegenesis as Spearman suggested. It is a matter of some interest that general reasoning and the minimax factor should appear together. It would suggest that the latter may possibly have much wider implications than are indicated by this particular study.

Of the greatest importance for the immediate purpose is Factor J, which is composed of Factors A, D, and F, Mechanical Experience or Information, Space II, and the Cybernetic factor. It would be only with considerable hesitation that this factor could be termed mechanical aptitude. It probably represents those elements of natural selection which combine to produce such cultural skills as mechanical aptitude, i.e., it is conceivable that interest, experience, and knowledge in a particular aptitude can be a function of the reward value of successful achievement, and that this successful achievement is a function of innate skills. This analysis again demonstrates the intimate relation between mechanical skills and the spatial factors, in particular, those factors which are concerned with the perception of movement in space. It should be noticed that Factor J is correlated (.39) with the second order reasoning factor and is quite independent (.01) of Factor K which seems to represent reading or perhaps scholastic ability.

BIBLIOGRAPHY

1. Guilford, J. P. (Ed.) Printed Classification Tests. Aviation Psychology Research Report 5. Washington, D. C.: U. S. Government Printing Office, 1947.

2. Thurstone, L. L. Multiple Factor Analysis. Chicago: The University of Chicago Press, 1947.

3. ------------. Primary Mental Abilities. Psychometric Monograph 1. Chicago: The University of Chicago Press, 1938.

4. Thurstone, Thelma Gwinn & Thurstone, L. L. Mechanical Aptitude II, Description of Group Tests. Psychometric Laboratory Report 54, 1949.

5. Thurstone, L. L. Mechanical Aptitude III, Analysis of Group Tests. Psychometric Laboratory Report 55, 1949.

TABLE 1

Centroid Factor Matrix

	I	II	III	IV	V	VI	VII	h^2
1	72	25	15	05	14	-23	-06	68
2	73	06	-04	-14	27	-17	-16	68
3	52	44	37	-11	10	09	11	64
4	55	32	41	-29	-13	24	-12	75
5	54	16	-04	-22	-16	13	07	42
6	51	-13	-32	-08	11	05	13	42
7	41	-41	12	-10	-17	-09	14	42
8	60	22	-32	17	-26	-10	10	63
9	48	15	-46	28	-24	13	-07	62
10	66	22	-03	17	18	08	-10	56
11	62	27	-08	11	08	-13	11	51
12	50	-26	-22	21	08	21	10	47
13	50	-18	-24	-28	-11	-10	-23	49
14	47	-08	16	14	14	06	-31	39
15	45	-40	30	14	17	16	21	57
16	53	-36	-08	-20	03	-12	08	48
17	38	-34	29	20	-25	-21	09	50

TABLE 2

Oblique Factor Matrix

	A	B	C	D	E	F	G
1	00	09	06	12	47	22	-06
2	-07	36	-03	-05	39	31	10
3	41	-09	01	00	32	-04	03
4	64	05	-02	03	-02	07	-05
5	36	22	20	02	07	-09	06
6	-05	31	22	-05	17	-03	32
7	05	28	-04	45	-02	-08	13
8	02	08	55	12	25	-05	-08
9	01	-02	68	-05	00	09	03
10	05	-04	28	-09	26	25	16
11	-01	04	28	03	44	02	04
12	-06	04	37	06	-01	05	45
13	01	54	03	03	00	22	-03
14	00	00	03	05	00	43	11
15	05	-04	-01	33	01	-01	49
16	-05	46	-04	23	12	01	22
17	-04	00	03	64	01	01	-04

TABLE 3

Transformation Matrix

	A	B	C	D	E	F	G
I	15	25	28	20	27	16	20
II	29	-32	23	-43	39	-09	-39
III	36	-34	-50	45	-06	04	-11
IV	-41	-78	56	24	03	21	06
V	-42	01	-39	-53	46	27	53
VI	64	-32	36	-39	-64	-08	61
VII	08	-11	16	27	38	-92	38

TABLE 4

Reference Vector Cosines

	A	B	C	D	E	F	G
A	100	-08	11	-04	-45	-31	05
B	-08	100	-41	-06	11	02	-07
C	11	-41	100	-02	-14	-16	13
D	-04	-06	-02	99	-03	-22	-24
E	-45	11	-14	-03	100	-16	-09
F	-31	02	-16	-22	-16	100	-18
G	05	-07	13	-24	-09	-18	100

TABLE 5

Correlations between Primary Factors

	A	B	C	D	E	F	G
A	100	06	06	23	56	49	15
B	06	100	40	11	00	09	06
C	06	40	100	10	14	19	-03
D	23	11	10	100	22	37	33
E	56	00	14	22	100	44	20
F	49	09	19	37	44	100	30
G	15	06	-03	33	20	30	100

TABLE 6

2d OrderlCentroid Factor Matrix

	I	II	III	h^2
A	61	26	30	53
B	32	-53	-12	40
C	36	-52	14	42
D	50	13	-30	36
E	62	26	32	55
F	68	23	07	52
G	38	21	-37	32

TABLE 7

2d Order Oblique Factor Matrix

	J	K	L
A	65	-02	03
B	-04	60	16
C	18	62	-05
D	08	04	50
E	67	-02	02
F	50	02	26
G	-02	-08	52

TABLE 8

2d Order Transformation Matrix

	J	K	L
I	57	35	43
II	25	-94	15
III	78	04	-89

TABLE 9

2d Order Reference Vector Cosines

	J	K	L
J	100	00	-41
K	00	101	-03
L	-41	-03	100

TABLE 10

2d Order Correlations between Primary Factors

	J	K	L
J	100	01	39
K	01	100	04
L	39	04	100

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